CURRENT STATUS OF CLEAN COAL TECHNOLOGIES IN THE APEC REGION

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ABSTRACT

Circulating fluidized bed (CFB) technology has proven itself during the last decade to be a viable concept for the clean combustion of coal and other solid fuels. Having met the most stringent environmental regulations in the world, CFB technology hence has established itself as the preferred choice for many new projects in the energy production industry. In addition to its capability to achieve low gaseous emissions without additional flue gas cleaning equipment, CFB technology has gained an advantage over the conventional coal burning technologies due to its fuel flexibility. With CFB technology, all types of coal can be utilized with minimal environmental impact, including the low-grade coals often available locally (and therefore economically) in many APEC economies. Additionally, CFB's can simultaneously burn biomass, thereby reducing operating costs and further reduce emissions and giving an overall improvement to the net CO_2 production.

Foster Wheeler Energy Inc. is the leading supplier of CFB technology and has a number of references for coal combustion in APEC economies. For example in Thailand, Foster Wheeler has supplied seven CFB boilers, that burn both domestic and imported coals. The first CFB unit in Thailand started up in 1993 and has since then successfully burnt local lignite together with bagasse pith and sludge from the paper mill.

The 300 MWe National Power Supply Co. (NPS) Power Plant, located in Tha Toom village of Prachinburi province, about 140 km north-east of Bangkok, started commercial operation in February 1999, and presents Foster Wheeler's latest CFB technology. The power plant is equipped with two matching Foster Wheeler circulating fluidized bed (CFB) boilers with a novel Compact solids separator.

The NPS Power Plant is feeding 60 percent of its power output to EGAT (Electricity Generating Authority of Thailand) under Thailand's small power producer (SPP) program. The process steam and the remainder of the power are sold to local customers of the Industrial Park 304 and to the nearby Advance Agro pulp and paper mill.

The Viet Namese Hongai # 8 anthracite coal, with very low volatile content of 6 %, has been burned as a main fuel in both units. Bituminous coal is an alternative coal up to full load for both units. Additionally local biomass (eucalyptus bark and rice husk) is burned in the second unit in an amount up to 50 % by energy input. Eucalyptus bark is a waste product of the paper mill.

Typically both boilers operate on daily cycling mode with 90 % load in daytime and about 60 % load during nights and weekends. All of the emission limits can be easily achieved.

PROJECT PROFILE – NATIONAL POWER SUPPLY CO. (NPS)

INTRODUCTION

Rapid growth in Thailand led to an average increase in power consumption of around 10 percent per year during the early 1990's, although it fell in 1997 as a result of the economic downturn throughout the region. At the end of 1997, the economy had total installed capacity of 16980 MW, an increase of 8 percent compared with 1996. EGAT operated 87 percent of the total installed capacity.

The Tha Toom project was launched in 1995 by Thai Power Supply Co. Initially, TPS studied the feasibility of building an IPP power plant at the Tha Toom site, adjacent to Soon Hua Seng's Advance Agro pulp and paper mill, but it soon became obvious that the decision-making process associated with an IPP project would take too long and that there might be an unwieldy number of bidders. Development therefore focused on a smaller cogeneration power plant, SPP, producing electricity, as well as steam for the mill and for local industrial customers. Later during the project TPS was renamed as National Power Supply Co. (NPS).

The contract for design and supply for two reheat boilers was awarded to Foster Wheeler Energia Oy (FWEOY), and was signed in June 1996. The hydrostatic pressure tests for the two boilers were successfully completed in January 1998 and in June 1998, respectively. The first coal fire took place in November. Boilers were handed over on May 3rd and on July 31st, in 1999. The boilers each produce 150 MWe with main steam flow rate of 482 t/h (134 kg/s) at 162 bar (a) pressure and 542 °C temperature burning Viet Namese Hongai # 8 anthracite as a main fuel and sub-bituminous coal as an alternative. One of the boilers is equipped to use biomass up to 50 % by energy. Biomass consists of bark from the nearby Advance Agro pulp and paper mill and rice husk from local suppliers.

NPS Power Plant in December 1999

DESCRIPTION OF BOILERS AND AUXILIARIES

The Compact CFB boilers of NPS were designed by Foster Wheeler Energia Oy, Finland, to generate 482 t/h of main steam and 440 t/h of reheat steam with similar pressure and temperature properties, 162 bar (a) and 542 °C temperature. Figure 1 shows the general arrangement of the boilers.

The Compact CFB concept is a second-generation circulating fluidized bed boiler design. The main difference between this and earlier designs is that the round cyclone of the traditional CFB boiler is replaced by a solid separator. This has a casing of rectangular cross section, which means that the unit can be joined to the furnace without expansion joints. The solids separator

Moreover, the solids return channels are fabricated using cooled, straight membrane panel walls. Thick, insulating refractories are not required in the design, only thin refractories are used in some locations for protection against wear. The main benefits of the new design are its compact size, cooled structure that recovers heat and low requirements for maintenance, which allow flexible, reliable and economical operation of the unit.

The operational experience of the Compact CFB units has proved the boiler to possess all the process benefits of a conventional CFB boiler. The technology is gradually being scaled up to larger sizes and 400 – 600 MW_e boilers will be available in the near future.

In the CFB design, fuel and bed material are fed into the lower portion of the combustion chamber in the presence of fluidizing air, which causes the fuel, ash and bed material to circulate and rise through the combustion chamber, finally entering the solid separator. The separator captures most of the circulating solids, including unburned fuel, and returns them to the furnace via return legs. This continuous circulation increases fuel residence time and results in very efficient combustion, while a relatively low combustion temperature of around 870 °C and the introduction of combustion air at various levels limits the formation of NO_x.

The boilers themselves are of natural circulation type, equipped with omega-type superheaters and reheaters located in the furnaces.

Because of the large amount of circulating hot material, the CFBC system is a very effective method of burning various grades of coal on their own, or mixed with low grade biomasses. Low SO_2 and NO_x emissions are relatively easy and inexpensive to achieve. SO_2 levels depend largely upon the sulphur content of the fuel, and can be reduced if necessary by injecting limestone into the bed, while low combustion temperature mean that NO_x emission can be kept low without any costly secondary reduction measures.

The fuel handling system consists of two parallel coal lines in the coal yard with coal pile reclaimers and a screening and crushing station. Coal is transported with long belt conveyors to the boilers, where there are two silos and two feeding lines into the furnace for both boilers. Biomass equipment consists of an unloading hopper in the biomass yard and belt conveyors, which transport biomass into two separate silos on the boiler. Biomass is mixed with coal in a

mixing screw and further fed into the furnace with a chain conveyor, robbing screws, rotary feeders and forced screws.

A four-field electrostatic precipitator, installed before the stack, is used for fly ash removal, and the ash it collects is transported by truck to an ash yard. The common 120 meters high concrete stack has two flues, one for each unit.

FUELS AND LIMESTONE

The NPS power plant has burned a very low volatile anthracite coal of the Hongai # 8 mine from Viet Nam as well as other economically feasible anthracite resources of the region including Chinese Hebi and Australian semi-anthracite, Jellinbah. Sub-bituminous coal was shortly utilized as an alternative fuel for anthracites.

Up to 50 % by energy has been produced on boiler # 7 with biomass, typically as a mixture of eucalyptus bark and rice husk. In addition, pure bark has been co-fired with the coal.

Analyses of typical fuels are presented in the table below.

Table 1 Typical Fuels

		Hongai # 8 Anthracite	Australian Jellinbah-anthracite	Chinese Hebi-anthracite	Eucalyptus bark	Rice husk
Total moisture	%	9	10	9	58	13
Ash (as rec.)	%	12	12	14	2.5	14.8
Volatile (dry)	%	4.8	13	13		
LHV (as rec.)	MJ/kg	27.8	26.0	26.0	5.0	12.7
Ultimate (MAF)						
C	%	92.5	88.2	88.1	48.8	46.2
H	%	3.4	3.8	4.6	5.8	6.9
O	%	2.1	5.3	5.5	44.9	44.8
N	%	1.4	1.9	1.5	0.4	0.8
S	%	0.6	0.8	0.3	0.02	1.3

Limestone can be fed to reduce SO2 emissions in flue gas, but due to the quite low sulphur content of the used coals, SO2 emission has been well under the regulation limit of 450 ppm (dry), typically on the level of 350 ppm (dry), and therefore limestone has not been used. The design limestone quality is presented in the following table.

Table 2 Limestone

CONSTITUENT		CONTENT
$CaCO_3$	%	97
$MgCO_3$	%	1.9
H_2O	%	0.1
Inert	%	1.0

COMMISSIONING

Since very different fuels were designed to be burned in the boilers; anthracite and biomass, some challenges had to be overcome during the commissioning period. The boilers were started with pure anthracite to make basic tuning of control loops first for anthracite only. After smooth operation with anthracite was achieved, the tuning for biomass cofiring was started in a systematic way.

The start-up period of the boilers, especially optimization of biomass firing was quite challenging due to properties of biomass. The biomass contained bark and rice husk, which differ very much from each other. Bark has very high moisture content, and the particle size is large.

Rice husk in turn, has low moisture content and consists of small and light particles. The differences in the fuel properties had impact on quality of bark and rice husk mixture and thus heating value of a biomass mixture fluctuated resulting in a process fluctuation, which was a challenge for tuning of the DCS.

Two major improvements during the commissioning period were a relocation of the bed temperature sensors and a modification of the start-up burners.

After successful commissioning period the boilers were handed over to the customer as scheduled.

OPERATING EXPERIENCES

Since commissioning the boilers have been successfully operated, mainly with anthracite. A cycling mode has been used for both boilers so that load is 90-100 % in daytime and about 60 % during nights between 10 pm. and 7.30 is. in order to support electric load demand of the national network.

In addition, Sub-bituminous Binungan coal was successfully burned during commissioning of the boilers resulting in good combustion efficiency and low emissions. Later, Binungan combustion was continued by mixing it in a 40 % portion with anthracite.

Burning of Australian semi-anthracite, Jellinbah with 16 % volatile content (DAF basis) took place on both units in autumn 1999 (during the second half of the first operation year) with good

operation experience. Chinese semi-anthracite, Hebi was fired in summer 2000 with good burning experiences.

Boiler turndown ratio is more than 1:3 on all fuel mixtures of boiler design, and full superheating (540 °C) is achieved both on superheater and reheater side from 40 % load upwards.

BIOMASS COMBUSTION

A waste product of the nearby Advance Agro pulp and paper mill, eucalyptus bark has been co-fired on boiler # 7 with anthracite up to 50 % by energy. Before combustion, bark has been mixed with an agricultural waste, rice husk, in the biomass yard resulting in a dryer biomass with higher heating value.

Due to quite big difference in biomasses, the quality of the biomass mixture, mainly its moisture, fluctuates dramatically. Therefore the quality of a biomass and coal mixture in combustion varies, requiring an advanced control system and high heat capacity of the circulation material of the CFB boiler.

PROCESS TESTS

Process tests were performed in August 1999 on Viet Namese Hongai # 8 anthracite and the results indicate efficient combustion with low emissions.

Boiler design data of full load compared to the measured values with pure anthracite and with biomass cofiring are given in the following table.

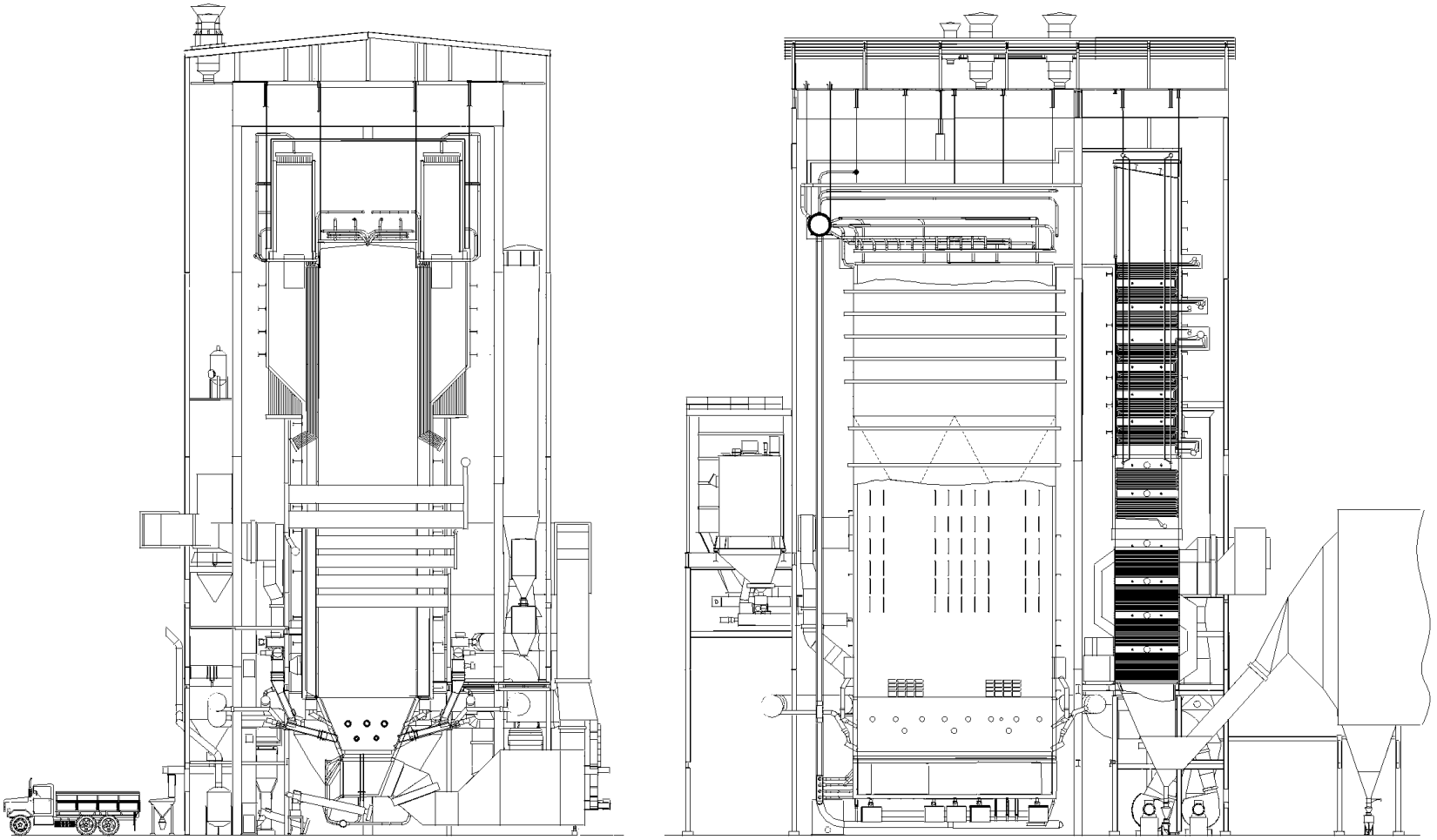
Table 3 Process Values vs. Design

		Design	**Hongai**	**50 % Hongai + 50 % Biomass by energy**	
Boiler load	% MCR	100	100	80	
Main steam flow	kg/s	134	134	107	
Temperature		°C	540	540	540
Pressure	barg	161	156	156	
Spray water flow	kg/s	3.3	3.4	4.3	
Fuel		Hongai # 8		Hongai # 8 + Biomass Mixture	
Moisture	% a.r.	8	7.2	47.5	
Ash	% a.r.	12	11.5	5.0	
Volatiles	% DAF	8	5.4	53	
Sulphur	% dry	0.7	0.52	0.1	
LHV as received (a.r.)	MJ/kg	27.79	28.3	9.3	
Fuel flow	kg/s	14.41	13.75	6.1+29.8	
Limestone	kg/s	-	-	-	
UBC loss of HHV	%	2.5	2.5	1.7	
UBC in ash		%	14.4	12.3	9.6
Boiler efficiency	%	91.7	92.0	90.3	
Emissions					
Flue gas O_2 in backpass	%-wet	3.32	2.87	2.5	
SO_2 (6 % O_2 dry)	ppm-dry	397	339	25	
NO_x	ppm-dry	180	34	30	
CO	ppm-dry	200	118	110	

In the future, different types of coals will be used alone or together with biomass on boiler # 7. Burning of Chinese semi-anthracite, Hebi, will continue and the Viet Namese anthracite, Hongai # 8 can be an important source of energy in the future as well if economical to purchase. Bituminous coals will be attractive alternatives, too, and will be selected for burning, if economically feasible.

Biomass will be mainly a mixture of eucalyptus bark and rice husk, and a proper mixing station is under erection to provide even quality and a continuous fuel stream to combustion.

CFB BOILER
2 x 370 MWth, 134/122 kg/s, 161/35 bar, 542/542 °C



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